ECOLOGICAL STUDIES ON THE SEEDLING GROWTH OF THE AFRICAN WALNUT, *TETRACARPIDIUM CONOPHORUM*

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OLUWOLE, S.O. & OKUSANYA, O.T. 1993. Ecological studies on the seedling growth of the African walnut, *Tetracarpidium conophorum*. Studies on the growth response of the seedlings of the African walnut, *Tetracarpidium conophorum*, to the effects of full sunlight, shade, soil types, soil moisture conditions, soil pH, soil salinity and mineral nutrients were carried out in greenhouse experiments. The seedlings responded to the effect of full sunlight and shade in the same manner in terms of all attributes measured. There was significantly better growth under the moist soil condition than the dry condition. Waterlogged condition resulted in seedling death. Humus soil enhanced growth significantly better than the other soil types tested. While the seedlings in humus had the highest values in the mineral nutrients analysed, those in clay and sand had the least. Growth significantly increased with increase in soil pH. There was a steady decrease in seedling survival and growth with increase in soil salinity. There was also a steady increase in sodium content and a steady decrease in other mineral elements in the seedlings as soil salinity increased. The absence of either nitrogen, phosphorus or potassium from the culture solution resulted in reduced growth, but the absence of nitrogen had the most pronounced effect on growth. The results were compared to those of germination studies and discussed in relation to the

berbanding dengan tanah liat dan pasir, yang mempunyai kandungan nutrien yang

Table 1. Some mechanical and chemical analytical data of the soils used in the growth experiments with *T. conophorum*. (Mean values are of three determinations)

	Mechanical analysis				Chemical analysis								
								Exchangeable ions					
Soil types	% Sand	% Silt	%Clay	Texture	pH	Organic matter	Soil moisture	K^+	Na^+	Ca^{2+}	Mg^{2+}	Chloride	Total
						g (100 *g* dry soil)$^{-1}$		*mmol* (100 *g* dry soil)$^{-1}$					N (%)
Humus	62	16	22	Sandy loan	7.2 ± 0.1	19.2 ± 1.5	22.1 ± 0.4	9.24	2.10	29.62	8.16	6.5	0.141
Red earth	46	2	52	Sandy clay	5.6 ± 0.2	8.2 ± 0.9	28.7 ± 0.3	0.50	2.30	0.20	2.80	5.7	0.040
Clay	13	8	79	Loamy clay	5.7 ± 0.4	12.5 ± 0.5	30.4 ± 0.3	0.51	2.60	0.85	3.62	1.8	0.050
Sand	85	7	8	Loamy sand	6.8 ± 0.1	3.7 ± 0.5	15.9 ± 0.6	2.04	2.40	0.72	2.94	2.1	0.189

Materials and methods

Seedlings

Seeds of *T. conophorum* were removed from the decaying pulp of fruits, which had fallen to the ground, from a population at Ikenne-Remo, Ogun State of Nigeria (7°10' N; 3° 28' E). They were germinated in sand moistened with tap water in seed trays after physical scarification with iron sponge and chemical scarification in 1% copper sulphate solution for 4 *h* (Oluwole & Okusanya 1993).

After two weeks of growth, uniform seedlings were transplanted into growth medium - either soil or sand in black polythene bags, 28 *cm* deep and 18 *cm* wide. (See Table 1 for properties of the growth medium). The seedlings were allowed to acclimatize for two weeks during which time they were watered with one-fifth strength Hoagland & Arnon (1938) solution.

All the experiments, except the shade experiment, were carried out in the greenhouse of the Biological garden of the University of Lagos, Nigeria. The shade experiment took place in a secondary closed forest near the Biological garden. A completely randomized experimental design was used for each experiment with six replicates per treatment. All studies used natural light with about a 12 ± 1*h* photoperiod. Temperature averaged 32 ± 2°*C* (day) and 25 ± 2°*C* (night) except in the shade where the average temperature was about 2°*C* lower. Relative humidity was about 80% at 09.00 *h*.

Effect of full sunlight and shade

One batch of seedlings planted in humic soil was placed in the open in the greenhouse where they received full sunlight; this constituted the full sunlight treatment. Another batch also planted in humic soil was placed on the floor of the secondary closed forest; this constituted the shade treatment. The amount of light in shade was about 30% that in full sunlight. Watering was to field capacity once a day.

Effect of soil moisture

Seedlings planted in humic soil were subjected to three watering regimes: dry, wet and waterlogged soil moisture conditions. Dry soil condition was achieved by watering the soil every four days, wet soil condition was achieved by watering everyday and waterlogged soil condition by keeping the soil completely immersed in water.

Effect of soil types

Growth of seedlings in four soil types designated as humic, red earth, clay and sand was compared. Seedlings were watered to field capacity once a day. Analysis of the soil types is given in Table I and the methods are given later in this paper.

Effect of pH

One-fifth strength Hoagland & Arnon (1938) solutions buffered and adjusted to pH 3.5, 5.5 and 7.5, using either dilute sulphuric acid or dilute potassium hydroxide, were used to water the seedlings in acid-washed coarse river sand. The pH of the sand was measured every other day to ensure that there was no large scale fluctuation.

Effect of salinity

Seedlings in humic soil were treated with sea water concentrations of 0, 10, 20, 30, 40 and 50% prepared by mixing proportions of sea water (salinity 3.3%) and distilled water. Seedlings which received high sea water concentration were [illegible] brought there in step-wise increment of 10% sea water per day (Okusanya *et al.* 1991).

Mineral nutrition

The seedlings were subjected to five nutrient treatments in sand culture. The first treatment was the one-fifth strength Hoagland & Arnon (1938) complete nutrient solution while the second, third and fourth treatments were the complete nutrient solution without phosphorus (- P), without potassium (- K) and without nitrogen (-N) respectively. The fifth treatment was the complete nutrient solution without nitrogen, phosphorus and potassium (- NPK). Initially, each seedling received 300 *ml* of appropriate solution every other day, but later each received the solution everyday.

In each experiment, except the mineral nutrition experiment where there was only one harvest after 12 weeks, there were two or three harvests at six-week intervals. At each harvest, six plants per treatment were randomly selected, carefully uprooted, washed clean of the growth medium and then separated into roots, stem and leaves. Leaf area was determined by a planimeter (PATON; CSIRO, Australia); thereafter the plant parts were dried in an oven at 80°*C* for 24 *h* and the dry weights determined. These values were used in calculating the total dry weight, leaf area ratio (LAR) as leaf area per unit dry weight; leaf weight ratio (LWR) as leaf dry weight in relation to total plant dry weight; stem weight ratio (SWR) as stem dry weight in relation to total plant dry weight; root weight ratio (RWR) as root dry weight in relation to total plant dry weight and shoot: root ratio (S:R) as the ratio of the sum of stem and leaf dry weights to root dry weight. The total dry weight and leaf area data were statistically tested by one-way analysis of variance.

Soil and plant tissue analysis

Soil pH was determined by a pH meter, soil moisture as loss of moisture by heating at 80°*C* for 24 *h* and organic matter as loss on ignition. Mechanical analysis of the soil particles was by the sieve method.

For cation determinations, soil subsamples were first leached with I N ammonium acetate while the dried plant tissues were ashed and the ash dissolved in 1% nitric acid. Sodium and potassium were determined by flame photometry, calcium and magnesium by absorption spectrophotometry. Chloride was determined by chloride electrode (EIL) in conjunction with an electrometer (Vibron) and total nitrogen by the semi-micro-Kjeldahl method. Available phosphorus was determined by spectrophotometry using a modified Trong (1930) method.

Results

The data on seedling growth in the last harvests in each experiment are only presented since most of the data of earlier harvests did not significantly alter the results. They are occasionally referred to in the text.

Effect of full sunlight and shade

There was no significant difference in the values of the dry weight and leaf area between the treatments. Other attributes measured in both treatments were also similar (Table 2).

Effect of soil moisture

All seedlings in the water logged soil regime died before the first harvest. Growth of seedlings in the moist soil regime was significantly better ($p < 0.1\%$) than in dry

Table 2. The effects of full sunlight and shade (Experiment I), soil moisture content (Experiment II) and soil pH (Experiment III) on the seedling growth of *T. conophorum* at the last harvest. All seedlings under the water logged condition died. Mean values are of six replicates per treatment ± SEM. In the same experiment, growth parameter values with the same superscript are not significantly different at the 5% probability level

	Light treatments		Soil moisture treatments		Soil pH treatments		
Growth parameters	Full sunlight	Shade	Moist	Dry	3.5	5.5	7.5
Mean total dry weight (*g*)	9.30 ± 0.62 [a]	8.95 ± 0.40 [a]	9.42 ± 0.58 [a]	3.80 ± 0.42 [b]	2.25 ± 0.20 [a]	3.86 ± 0.48 [b]	9.40 ± 0.56 [c]
Mean leaf area (cm^2)	75.20 ± 6.50 [a]	72.00 ± 8.20 [a]	76.10 ± 5.50 [a]	37.50 ± 2.62 [b]	20.60 ± 4.10 [a]	31.52 ± 4.30 [b]	72.22 ± 3.11 [c]
Leaf area ratio ($cm^2 g^{-1}$)	80.86 ± 0.99	81.80 ± 1.41	80.79 ± 1.18	98.68 ± 3.09	91.56 ± 2.74	81.66 ± 3.35	76.83 ± 1.64
Leaf weight ratio (% of total dry wt)	26.05 ± 1.43	26.13 ± 1.78	25.35 ± 0.67	20.15 ± 1.70	16.62 ± 1.17	23.24 ± 2.38	24.83 ± 0.96
Stem weight ratio (% of total dry wt)	45.22 ± 0.65	45.66 ± 0.71	44.50 ± 0.70	50.53 ± 2.22	46.04 ± 1.80	48.93 ± 2.01	44.78 ± 0.68
Root weight ratio (% of total dry wt)	28.73 ± 0.94	28.26 ± 1.30	30.16 ± 0.21	29.32 ± 1.67	32.65 ± 2.28	27.83 ± 2.76	30.39 ± 0.58
Shoot : root ratio	2.48 ± 0.11	2.55 ± 0.16	2.32 ± 0.03	2.49 ± 0.20	2.10 ± 0.22	2.63 ± 0.38	2.28 ± 0.06

Table 3. The effects of different soil types on the seedling growth of *T. conophorum* at the last harvest. Mean values are of six replicates ± SEM. Values with the same superscript are not significantly different at the 5% probability level

Growth parameters	Soil types			
	Humus	Red earth	Clay	Sand
Mean total dry weight (*g*)	13.99 ± 0.62 [a]	10.82 ± 0.80 [b]	10.07 ± 0.52 [b]	8.90 ± 0.23 [c]
Mean leaf area (cm^2)	86.00 ± 2.40 [a]	68.72 ± 4.55 [b]	63.55 ± 2.75 [b]	57.20 ± 3.44 [c]
Leaf area ratio ($cm\ g^{-1}$)	61.41 ± 0.82	62.54 ± 3.62	63.12 ± 3.71	64.27 ± 1.91
Leaf weight ratio (% of total dry wt)	20.44 ± 1.88	19.43 ± 3.98	16.91 ± 2.14	16.27 ± 2.93
[illegible] (% of total dry wt)	47.05 ± 1.64	52.99 ± 2.51	45.60 ± 1.47	46.25 ± 1.32
Root weight ratio (% of total dry wt)	32.52 ± 1.63	27.57 ± 1.60	37.49 ± 0.67	37.47 ± 1.73
Shoot: root ratio	2.08 ± 0.16	2.64 ± 0.20	1.67 ± 0.05	1.66 ± 0.11

Effect of soil types

In each of the soil types used, there were increases in dry weight and leaf area with time although at different rates (data not shown). The best growth was in humic soil and it was significantly better than the other three soil types. At the first harvest, there was no significant difference in growth between seedlings in the four soil types. At the last harvest, growth in red earth was significantly better than in clay soil ($p < 0.1\%$) which in turn was significantly better ($p < 0.1\%$) than in sandy soil ($p < 0.1\%$) (Table 3).

Red earth produced the highest SWR value and clay produced the least. RWR was, however, highest in clay and least in red earth. The leaf area ratio in sand was the highest while the least value was in humus. The reverse was the case with LWR (Table 3).

The determination of the mineral elements in the seedlings grown in the various soil types shows that potassium contents of the seedlings in all soil types were virtually the same. In general, seedlings in humus had the highest values for all the other mineral nutrients analysed except for sodium which was highest in sand (Table 4).

Table 4. The mineral element content of *T. conophorum* seedlings grown in the various soil types. Mean values are of six replicates ± standard error (SE)

Soil type	K^+	Na^+ (m equiv/100 *g* dry sample)	Ca^{2+} (m equiv/100 *g* dry sample)	Mg^{2+}	P *ppm*	Total Nitrogen (%)
Humus	3.52 ± 0.28	0.24 ± 0.04	3.20 ± 0.20	2.02 ± 0.12	1.26 ± 0.07	15.09 ± 1.31
Red earth	2.99 ± 0.31	0.28 ± 0.03	1.75 ± 0.12	1.60 ± 0.08	0.26 ± 0.05	13.45 ± 1.18
Clay	3.52 ± 0.34	0.86 ± 0.07	2.86 ± 0.30	1.14 ± 0.09	0.59 ± 0.08	1.18 ± 0.07
Sand	3.26 ± 0.31	1.96 ± 0.08	2.44 ± 0.15	1.43 ± 0.09	0.32 ± 0.06	6.75 ± 0.93

Effect of salinity

There was a steady decrease in seedling survival, dry weight and leaf area as salinity increased. While LWR and S:R decreased, LAR and RWR increased as salinity increased (Table 5). The sodium content in seedlings increased with salinity while the values of the other elements decreased (Table 6).

Mineral nutrition

The absence of any or all of nitrogen, phosphorus or potassium in the culture solution caused significant reduction in seedling growth. Growth was significantly better in the complete culture solution than in that lacking phosphorus ($p < 5\%$), which in turn was significantly better ($p < 1\%$) than in that lacking potassium. This was significantly better than in that lacking nitrogen or lacking all the three elements ($p < 0.1\%$) (Table 7).

Table 5. The effects of salinity on the seedling growth of *T. conophorum* at the last harvest. Mean values are of six replicates ± SEM. Values with the same superscript are not significantly different at the 5% probability level

	Sea water concentrations %					
Growth parameters	0	10	20	30	40	50
Survival (%)	100	70	30	10	10	10
Mean total dry weight (g)	6.95 ± 0.20 [a]	3.35 ± 0.33 [b]	2.08 ± 0.41 [c]	1.45 ± 0.28 [d]	0.26 ± 0.32 [e]	0.15 ± 0.09 [e]
Mean leaf area (cm^2)	62.41 ± 3.40 [a]	43.00 ± 4.50 [b]	28.08 ± 1.77 [c]	23.41 ± 1.48 [c]	14.52 ± 1.00 [d]	10.20 ± 1.00 [d]
Leaf area ratio ($cm^2 g^{-1}$)	89.80 ± 1.15	128.36 ± 5.52	135.31 ± 4.30	161.45 ± 24.62	558.03 ± 54.27	680.66 ± 83.53
Leaf weight ratio (% of total dry wt)	30.11 ± 2.80	25.72 ± 6.71	20.80 ± 4.89	11.30 ± 7.80	0.008 ± 0.014	0.005 ± 0.01
Stem weight ratio (% of total dry wt)	45.43 ± 0.84	35.76 ± 1.05	39.92 ± 1.11	44.18 ± 0.83	34.35 ± 1.52	27.54 ± 2.60
Root weight ratio (% of total dry wt)	24.56 ± 2.13	38.52 ± 1.38	39.29 ± 1.63	44.51 ± 1.94	62.62 ± 2.16	71.95 ± 2.67
Shoot : root ratio	3.10 ± 0.35	1.68 ± 0.50	1.66 ± 0.68	1.32 ± 0.48	0.60 ± 0.21	0.45 ± 0.36

Table 7. The effect of various combinations of nitrogen, phosphorus and potassium on the seedling growth of *T. conophorum*. Mean values are of six replicates ± SEM. Values with the same superscript are not significantly different at the 5% probability level.

Table 8. The mineral nutrient content of *T. conophorum* seedlings grown at various combinations of nitrogen, phosphorus and potassium in the growth medium. Mean values are of six replicates ± SEM

Combinations of nitrogen, phosphorus and potassium in the growth medium	K^+	Na^+	Ca^{2+}	Mg^{2+}	P	Total Nitrogen
		m equiv/100 *g* dry sample			*ppm*	(%)
Complete culture solution with NPK	5.92 ± 0.35	3.22 ± 0.24	4.52 ± 0.4	1.72 ± 0.09	2.22 ± 0.12	15.31 ± 1.35
Complete culture solution without phosphorus (-P)	6.48 ± 0.42	1.36 ± 0.04	2.41 ± 0.1	1.31 ± 0.05	0.28 ± 0.02	9.78 ± 1.04
Complete culture solution without potassium (-K)	1.59 ± 0.09	2.11 ± 0.14	3.30 ± 0.31	1.74 ± 0.07	0.88 ± 0.05	9.84 ± 1.05
Complete culture solution without nitrogen (-N)	2.95 ± 0.08	0.59 ± 0.08	1.94 ± 0.09	1.32 ± 0.03	0.53 ± 0.03	2.58 ± 0.18
Complete culture solution without nitrogen, potassium and phosphorus (-NPK)	1.55 ± 0.07	0.37 ± 0.03	1.53 ± 0.07	0.63 ± 0.04	0.13 ± 0.01	1.94 ± 0.09

species since the forest soil is wet for most part of the year, not only because of the heavy rainfall (< 3000 *mm* y^{-1}) which lasts for about nine months but also because of heavy forest litter and the closed forest canopy both of which result in low evapotranspiration. Similar results have been reported for some other forest species (Okusanya *et al.* 1991).

The low leaf area developed under the dry treatment (Table 2) was caused by the [redacted] area (the photosynthetic organ) between the dry and moist treatments may be responsible for the difference in their dry weights. The poor growth of *T. conophorum* in dry soil may partly explain its absence from the dry deciduous forest and savanna zone of Nigeria.

Abeles (1973) reported that high soil water regime (water logging) causes poor aeration which results in low soil oxygen content and suffocation of roots which may lead to poor growth and subsequent death of seedlings such as reported here. All these may partly explain why *T. conophorum* is absent from the fresh water swamp and the river banks in Nigeria.

The similar response of *T. conophorum* at the first harvest to the different soil

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